U.S. Coast and Geodetic Survey
Elements of chart making

DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
E. LESTER JONES, Superintendent

ELEMENTS OF CHART MAKING

BY

E. LESTER JONES
SUPERINTENDENT

Special Publication No. 38

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

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PREFACE

There are few people who realize, and therefore fully appreciate, the enormous amount of both technical and practical detail necessary in the making of a chart for the use of the navigator and nautical man.

During the past year the United States Coast and Geodetic Survey distributed nearly 163,000 of these charts, which represented nearly half a million impressions on the printing presses. While this single feature that produces the finished product means much careful work, the preliminaries in connection with the making of a chart, covering many months of hard, thoughtful, accurate work, are not in even a small measure understood by the average person.

It is due to this last reason that this nontechnical book has been prepared, in an endeavor to outline in a clear and practical manner, from the beginning, just the process of nautical chart making. In other words, this is a primer, showing by illustration and text each stage in the field work, on through the office detail until the chart is completed and ready for distribution.

The absence of scientific and technical terms is intentional. They are eliminated so that even the younger element in the schools throughout the country can form a clear and concise interpretation of this phase of the Government's work, and of its value to the people of the United States as well as to other countries who have a navy or merchant marine.

The charts are used for the safe guidance of vessels, not only by the Navy, Coast Guard, and Merchant Marine, but by privately owned vessels as well.

Further emphasis can properly be placed on the fact that no navigator, wherever his voyage may take him, feels himself secure without these charts.

As signals are essential to the guidance of the locomotive engineer, so are the charts of the United States Coast and Geodetic Survey essential to the guidance of the navigator.

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ELEMENTS OF CHART MAKING

THE NECESSITY FOR SURVEYS

To appreciate the great value of a nautical chart one has to imagine himself a surveyor in a land which is strange to him, standing on the shore of some body of water which has never appeared on any map.

Look upon this water as a highway leading to a fertile area abounding not only in mineral resources but rich for the farmer, and which must be made accessible to the pioneer through the efforts of the surveyor. This highway must be cleared of all dangers and made safe and passable for traffic. To the surveyor, the method is clear, but he must be able to mark the safe road for those who will use it. There are channels to be followed; dangerous reefs and shoals that must be located and avoided, so he draws and completes a plan or outline of the best and safest way for ships to go and sends forth this information to the navigator.

The body of water that the surveyor is viewing is to him not different from other navigable streams. There are apparently several channels, dangerous reefs, and shoals that must be located, and then their exact positions placed on a nautical chart before this water may be safely navigated. It is necessary for the shore line, mountains, and other topographical features to be properly located and also made part of the chart so the officer guiding his ship may, by these means, determine the exact position of his vessel with reference to the unseen dangers below the surface of the water.

In this or any new or undeveloped country there are no monuments which are the results of careful surveys. The surveyor therefore must determine the position of his starting point by observations upon objects in the heavens.

Conditions such as these are found in portions of Alaska and our other possessions, and existed in the country used for illustration before accurate charts were made. To insure absolute safety and to protect human life and commerce all unsurveyed waters must be charted, and the charts must be kept corrected as to changes made by the hand of man and by nature. Insurance

companies will not insure vessels plying through uncharted waters except on the payment of exorbitant rates. Naturally, the passenger and the consumer of the freight must pay this extra cost. Therefore a general and clear description of the work of making or constructing the chart which contributes largely to the safety of the waters wherever they may be is of vital interest to everybody.

STARTING THE WORK

The engineer in starting his work makes a rough sketch or diagram of the area to be surveyed. This sketch often bears little resemblance to the final survey, but serves as a preliminary index to the progress of the work.

In beginning surveying operations it is generally desirable to select a level stretch of land on which a line, called a base line, can be measured with a standardized metal tape. A point, which will serve as one end of the base line, is selected and we will call this point the starting point. This point is shown in figure 1.

The latitude and longitude of the starting point must be exactly determined. This process requires very accurate astronomical observations, and may briefly be defined as *finding distances from the equator* (latitude) and *from a reference meridian* (longitude) by means of these observations. The instruments for this work are shown in figures 2, 3, and 4.

DETERMINATION OF THE TRUE NORTH

To anyone seeking only general knowledge of this important subject the above explanation will suffice for the first step. The operation to determine true north is the next step of interest. After the latitude and longitude of the starting point are determined the direction of true north is determined from this point, usually by observations on the north star (Polaris). (See figure 5.)

A signal pole is then placed on the ground exactly in the true meridian of the starting point and this enables the surveyor to determine at any time the angle of deviation of the magnetic needle from true north. It might be well to state for general information that the magnetic needle does not point true north (except at a very few places), as the deviation varies at different places and for different times.

To enable navigators, surveyors, engineers, and others properly to allow for this deviation, observations are made at many points. The true north point is known as zero, and the number of degrees

east or west of this zero to which the magnetic needle points, is the variation of the compass, which is shown on each nautical chart. The observations for this deviation of the needle are made with the instruments shown in figure 6.

In the first operation the position of a *starting point* upon the earth was determined by observations upon objects in the heavens—latitude and longitude. In the second operation a direction from this point true north was ascertained also by astronomical observations. From this direction the variation of the magnetic needle may be obtained. In the third operation a line was measured from this starting point, and the direction of this line was determined by reference to the true north, ascertained in the second step.

BASE-LINE MEASUREMENT

The line measured is known as the base line. Its length must be very accurately determined, for it is used as the basis in the computations of the lengths of hundreds of other lines that are not actually measured. Formerly the measurement of a base line was made by bars, sometimes placed in ice to maintain an even temperature. Figure 7 shows a party at work with the bars. Now, a tape of a nickel-steel alloy is generally used, which shows so little change in length caused by differences of temperature that its results are as accurate as those of the old and cumbersome bar. (See figure 8.) When the length and direction of the base line are determined, its ends are two points whose exact positions upon the earth are known, one having its position observed and the other computed. The base line is the shortest distance between these points, and its length is accurately known. The progress of the work to this point is represented in figure 9.

TRIANGULATION

A third point is selected off to the side of the base line, and the lines connecting this new point with the base ends will form two sides of a triangle of which the base line is the third side. Then the first triangle of the triangulation system has been located. Its angles must be accurately measured and satisfy the geometric condition that "the sum of the angles of a triangle must equal two right angles" (180 degrees). Now, having ascertained the angles of this triangle and knowing the length of the base line, which is one side of the triangle, the other sides may be computed by the trigonometric proposition that "when any three elements (sides

and angles) of a triangle are known, at least one being a side, the other elements may be determined by computations." When the other sides of the first triangle are computed, those sides are used in place of base lines for new triangles and the triangulation system is, in this manner, continued over the area to be surveyed. If the sides of the triangles are very long, the curvature of the earth must be considered in their computation. The instruments and methods used in triangulation, the type of signal observed upon, and the manner in which the stations are marked are shown in figures 10 to 13. The progress of the survey after the triangulation has been completed is represented in figure 14.

Starting from a point whose exact latitude and longitude, and also the true meridian passing through it, are determined by observations on the stars; then from this point measuring a line whose direction and length are ascertained; then with this line as a side of the first triangle, forming a series of triangles whose angles and length of sides are precisely determined, the latitude and longitude of the vertices of all the triangles are computed from these data with an accuracy substantially equal to that of the starting point. By this means a controlling triangulation net has been placed over the area of which a topographic survey is to be made.

MAPPING THE LAND AREAS WITH THE PLANE TABLE

Before the measurement of the angles of the triangles, signals were placed over the triangulation stations. The topographic party, when ready to begin work, is equipped with a plane table, alidade, stadia rods, and a sheet known as a "projection," on which the lines of latitude and longitude are drawn to a selected scale; and the vertices of the triangles, called triangulation points or stations, are plotted in their correct geographic positions. By the plane-table method, field notes are not necessary, both the survey and drawing being made in the field at the same time.

The plane table, with the projection clamped to its top, is so set up at points in the field that the triangulation stations on the sheet are in exact relation with respect to direction to the signals over the same stations on the ground.

The alidade consists of a telescope attached to a straightedge so that the two are in parallel vertical planes. If the straightedge is in contact with a point representing the place occupied by the plane table and the telescope is sighted at an object and a line is drawn along the straightedge on the topographic sheet, then the

object is somewhere on this line. This gives the *direction* to the object. Its *distance* is ascertained by a reading made on the stadia rod held on the object. In making the survey the observer places the alidade on the point on the sheet which corresponds to the point on the ground over which the plane table has been set; the stadia man follows the shore line, stopping at every bend. The observer locates the position of the stadia rod at each bend of the shore line, connects these positions on the sheet, and the shore line is thus surveyed and mapped. The use of the plane table is illustrated in figures 15 and 16.

Other features than the shore line, such as prominent buildings, roads, woods, etc., are located in the same manner; that is, by placing the stadia rod on the object, then with the alidade ascertaining its direction and distance, and plotting this on the sheet. The map or chart has now been completed to the extent shown in figure 17,

In beginning the survey, the position of a point was established; a line was measured from this point; this line was taken as the base of the first triangle; the lengths of the other sides of this triangle were computed and used for bases for new triangles; these triangles were extended over the area to be surveyed; the points of these triangles were used to establish the position and orientation of the plane table; the topography was filled in by the plane table and a map was made. With one more operation this map becomes a chart—a guide for the mariner by which he locates the safe channels and avoids the hidden dangers of the waters.

SURVEYING THE WATER AREAS

The agency which performs the operation which changes the map into the chart is known as the hydrographic party. This party usually does its work from a launch; sometimes from a large vessel; sometimes from a rowboat. The party consists of two observers with sextants, a recorder, a leadsman, and a crew. The position of the sounding is determined by the observers in the moving sounding boat by sighting with sextants upon the signals, shown in figures 18 to 20, over the triangulation points or other established conspicuous objects; the leadsman drops his line overboard and ascertains the depth of water; he calls out the depth and the observers announce the angles; the recorder enters the angles and the depth in his field book. Thus, the sounding is made, located, and recorded. This sounding, and thousands of

others made in the same manner, are plotted on the field sheets in exact relation to the triangulation stations and other objects on land and also to the shore line. All aids or dangers to navigation are similarly plotted on field sheets and later appear on the published chart, with the soundings. The location of the soundings on the field sheet and chart is shown in figures 21 and 22. Figures 23 to 25 show different methods of making soundings with the lead line.

This information, which guides the mariner along safe channels and past the dangers, was obtained from boats by observations upon objects on shore. Later the mariner, by making observations upon the same objects or other landmarks equally well located, determines the position of his boat with relation to the channels and the dangers, by plotting his observed angles or compass bearings on the chart.

In connection with the hydrographic survey the rise and fall of the tide is observed at frequent intervals and the depth of water is given on the chart as it is at the average low tide.

Surveying our waters for navigational charts has in the past largely been done by means of sounding with the lead line, and for the reason of the limitations of that method the information as to the form of the bottom so obtained is restricted to points more or less separated. In other words, the hand lead, weighing about 12 pounds, is attached to a line and cast overboard at various intervals to ascertain the depth of water, and does not give a complete or final knowledge of certain water areas.

THE WIRE DRAG

Until quite recently the lead-line method was the sole dependence of the chart maker. That it is untrustworthy as applied in many localities is apparent. With the recent greatly increased importance and exacting requirements due to the deeper draft vessels, the opening up of new water areas, the greater demands of our Navy, and in general a greater necessity for absolute accuracy owing to frequent marine disasters, its defects became alarming.

The most important forms of these menaces, not generally found by the use of the older method, are rocky pinnacles, ledges, bowlders, coral reefs, etc. As surveys by the lead-line method failed frequently to reveal even an indication of their presence, it became more and more evident that some new device specially adapted to the requirements of such localities was urgently needed.

For this purpose the wire drag was adopted. From its crude original form there has been rapidly developed, by the Coast and Geodetic Survey, an apparatus which in practice gives absolutely accurate results that are final.

It consists of a horizontal bottom wire, supported at intervals by adjustable upright cables suspended from buoys on the surface. These uprights can be lengthened or shortened for various required depths, and to maintain the bottom wire at a given depth below the surface of the water by making allowance for the rise and fall of the tide. The uprights are maintained in a nearly vertical position by means of weights attached to their lower ends.

Intermediate between the uprights wooden floats are attached directly to the drag wire to prevent sagging between the uprights. The end weights and buoys are larger than the intermediate, and to them the towing gear from the launches is attached.

OPERATION OF THE WIRE DRAG

In operation the drag is extended by directing the course of the launch outward from the middle of the drag as well as forward along the center of the area to be swept. In some instances the forward motion of the drag is due entirely to the current, and when this is the case the effort of the launches is expended entirely in maintaining the drag in an extended form. An interesting feature of the apparatus is the signaling system between the end launches, made necessary on account of the great length of the drag, which is sometimes 4 to 5 miles long.

Upon meeting an obstruction in its course the drag at once indicates the obstruction and points out its location. As soon as the drag wire touches the obstruction there is a marked increase in the tension on the drag, which is noted immediately on the spring balance to which the tow line is attached; and the position of the shoal is shown by the buoys, which line up between the obstruction and the launches. A buoy is then placed at the intersection of the two lines of drag buoys, the drag is cleared and moved ahead on its course, and the detailed examination of the spot is then made by a sounding party in a small tender or sounding boat. The operation of the wire drag and the necessity for its use are graphically shown in figures 26 to 29.

The great length of the drag and the maintenance of an ample overlap along adjacent dragged strips insure the completeness of the operation; and the stability of the drag wire at the required

depth, and its certain indication of any contact with the bottom, give ample assurance of the certainty of its results.

The hydrographic survey completes the field work. As a result of the several operations in the field we have some books with the various records of observations and sheets on which are represented the topographic and hydrographic features. This information must be arranged in the most serviceable form for the mariner and placed on metal plates in order that it may be printed for general distribution and sale. This is the duty of the office force.

OFFICE WORK IN MAKING THE CHART

The computers make the precise computations necessary to accurately show the latitude and the longitude of each of the control points, the variation of the magnetic needle, the direction and strength of the currents, and the plane of reference, which is the mean of the low waters to which the observed depths of waters are reduced.

All material received in the office affecting nautical charts, including surveys by the United States Coast and Geodetic Survey, other branches of the Government, State and municipal officials, and by other authorities, is referred to the drafting room where it is indexed for ready reference.

The hydrographic work of the Survey is usually received with the soundings plotted on the field sheets in pencil. These are verified and inked before they can be used for charting purposes.

The first step is the determination of the scale of the proposed chart. The commercial importance of the locality, the characteristics of the bottom, and the area to be covered are the controlling factors in determining the scale.

A drawing on paper, known by the draftsman as *the rough drawing*, is then made. Lines representing arcs of parallels of latitude and meridians of longitude are drawn and verified. This system of lines is known as the *projection* and serves as the control of the drawing. On the published chart it enables the mariner to plot the position of the ship when its latitude and longitude are known; or to scale the latitude and longitude of his ship's position from the chart when such position has been determined graphically on the chart by dead reckoning or bearings on shore objects.

The next step is to reduce and draw in the shore line and such topographic features as are to appear on the chart, special con-

sideration being given to those features that will be useful to the mariner in determining the position of his ship. All objects of prominence which can be seen from the water areas, such as lighthouses, beacons, range marks, church spires, towers, etc., are carefully plotted on the drawing by means of their geographic positions as determined by the triangulation. All other topographic features are compiled from the plane-table sheets.

In order to make safe entry into harbors, roadsteads, etc., the mariner consults the chart for soundings noted thereon. At the same time, however, he must allow for the state of the tide at the time. This information is obtained from the tide table, which, published annually one or two years in advance, gives the times and the heights of high and low waters of practically all the coastal waters in the world visited by ocean-going vessels.

Only with the aid of a specially designed machine is it practicable to master the amount of the computations required to predict these heights and times with the necessary accuracy for so many stations. This machine, when set for a particular station and some future year, takes into account the tide-producing forces of the sun and moon, as known astronomically, and the modification of their effects by the conditions peculiar to the particular station, which latter are determined once for all by the analysis of a series of tidal observations at the place made in the past. These data, kept on file, are set up in the machine. This requires about two hours. In about seven working hours the operator tabulates, on a form ready to go to the printer, the day, hour, and minute, and the feet and tenths of each high and low water in one year for that station. (See figure 30.)

The *soundings* and then the *depth curves* which connect all points having the same depth, 5 fathoms for instance, are added to the drawing. As the field sheets are usually on a much larger scale than the chart and have as many of the soundings as can be plotted on the sounding lines, only a small percentage of such soundings can be shown on the chart. The accuracy and clearness of the chart depends on an intelligent selection of the soundings. Critical depths which mark changes in the slope of the bottom must not be obscured by crowding in less important ones, and the selection must be made to show clearly all safe areas as well as all dangerous features developed by the surveys. The nature of the bottom material is also indicated at frequent intervals. The curves connecting points of equal depth are

of great value in showing the general configuration of the bottom, in emphasizing shoal spots, and in indicating the areas over which ships of known draft can be safely taken. To guard against mistakes the drawing is then verified by other draftsmen, and after verification it is examined and approved by the chief draftsman.

ENGRAVING AND PRINTING

If the chart is to be engraved on copper, the drawing is then turned over to the engraver. If it is to be published by lithography, which is usually the case, as the chart will then reach the public much sooner, a finished drawing is made on tracing cloth. All the artistic skill of the draftsman enters into this drawing, limited by the rigid requirement that every line and dot made in the drawing must be absolutely opaque.

Owing to frequent changes, the buoys, beacons, range marks, and range lines, and the characteristics of the lights are added to the copperplate or finished drawing just before the chart is printed.

The chart reaches the public through three different processes of printing. First, by a direct print from copperplate; this process gives the clearest possible chart and is used especially for charts of small scale covering extensive areas or those having detailed information. Second, by transfer from the copperplate to an aluminum plate and then printing by the lithographic process. Third, by transferring directly from a drawing to an aluminum plate and printing by the photolithographic process.

SUMMARY

Starting with a point; then a line from this point; a triangle from this line; new triangles formed on the first; signals over triangulation points; topography filled in by plane table; hydrography surveyed; computations made; compilation sheet drawn; smooth drawing made; plate engraved; plate electrotyped; the chart, printed or lithographed, then goes to the mariner.

The charts are sold for amounts which cover only cost of the paper and the printing. Portions of finished charts are shown in figures 31 and 32.

The outline is simple, but long years of training in each branch is necessary to prepare the officers of the Survey to make this important safeguard to human life and property which also makes accessible new lands and their products.

BOOKS WHICH GIVE DETAILED INFORMATION

The books in the list given below may be consulted for the technical details of various operations of the Coast and Geodetic Survey and for further information in regard to the methods employed. These books may be obtained on application to the Division of Publications of the Department of Commerce, Washington, D. C.

Special Publication No. 5, Tables for a Polyconic Projection.

Special Publication No. 8, Formulæ and Tables for the Computation of Geodetic Positions.

Special Publication No. 14, Determination of Time, Longitude, Latitude, and Azimuth.

Special Publication No. 19, Primary Triangulation on the One hundred and fourth Meridian, and on the Thirty-ninth Parallel in Colorado, Utah, and Nevada.

Special Publication No. 22, Precise Leveling from Brigham, Utah, to San Francisco, Cal.

Special Publication No. 23, U. S. Coast and Geodetic Survey, Description of its Work, Methods, and Organization.

Special Publication No. 26, General Instructions for the Field Work of the U. S. Coast and Geodetic Survey.

Special Publication No. 28, Application of the Theory of Least Squares to the Adjustment of Triangulation.

Appendix 7 of the Report for 1905, Plane Table Manual.

Appendix 6 of the Report for 1905, Long-Wire Sweep.

Special Publication No. 21, Long-Wire Drag.

Special Publication No. 29, Wire-Drag Work on the Atlantic Coast.

Principal Facts of Earth's Magnetism, 1902.

Directions for Magnetic Measurements, 1911.

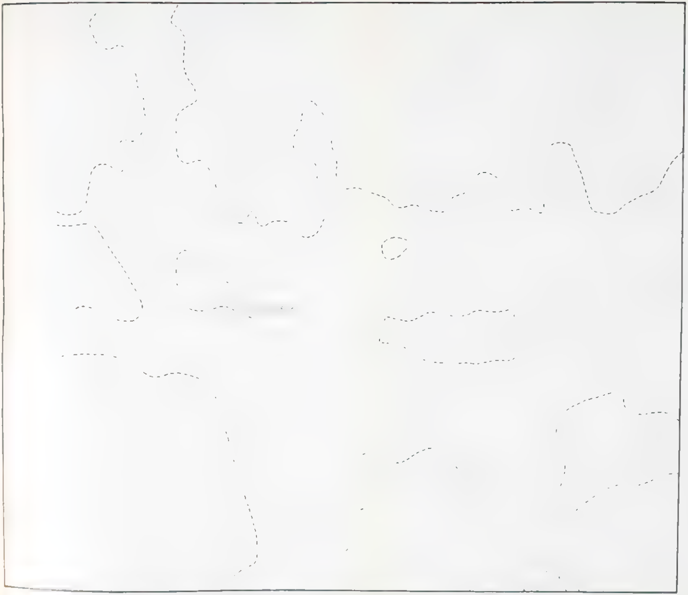


Fig. 2.—A FIELD ASTRONOMIC STATION AT WHICH THE LATITUDE IS BEING OBSERVED.

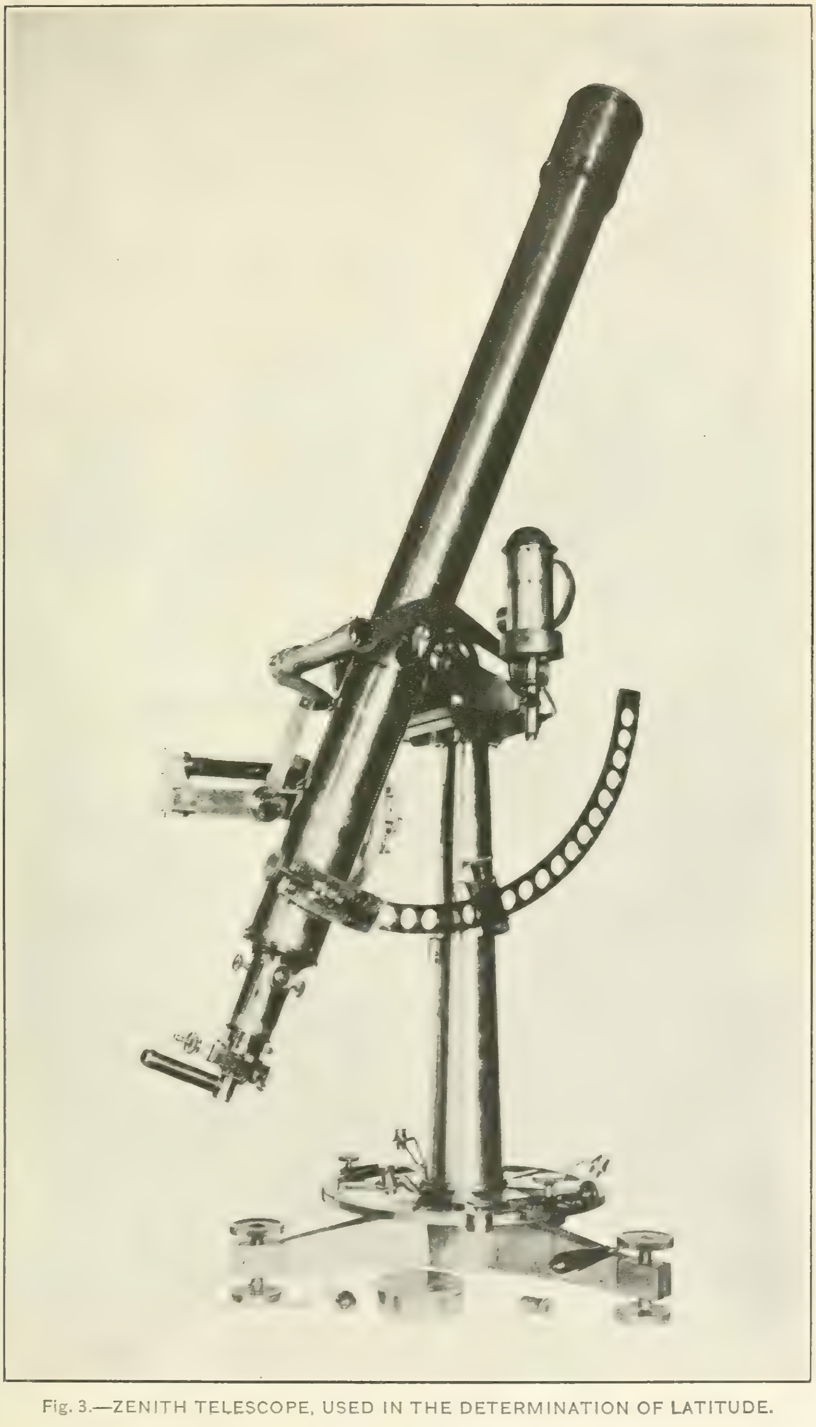


Fig. 3.—ZENITH TELESCOPE, USED IN THE DETERMINATION OF LATITUDE.

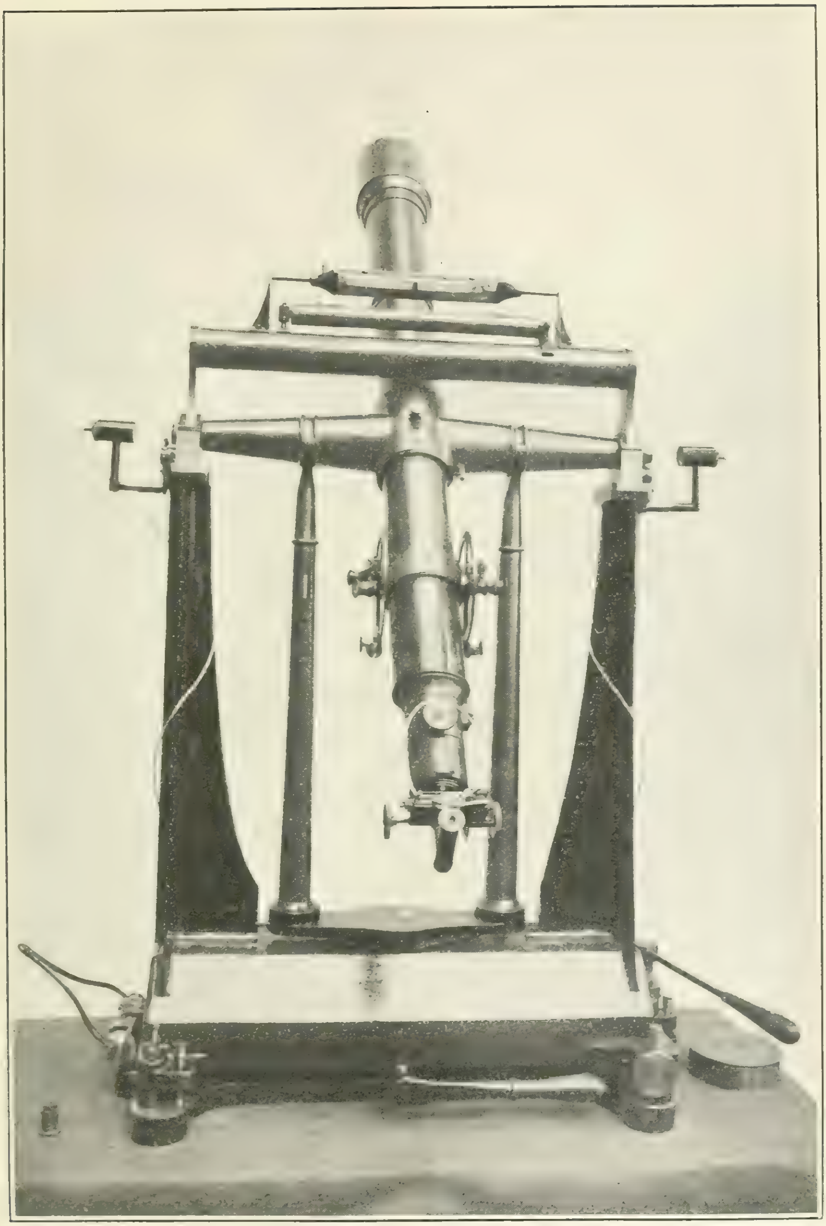


Fig. 4.—ASTRONOMIC TRANSIT, USED IN THE DETERMINATION OF TIME AND LONGITUDE.

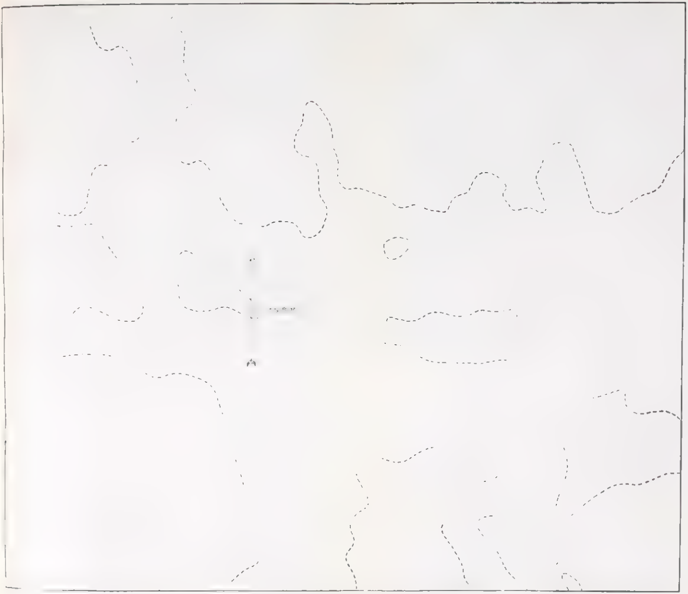


Fig. 6.—MAGNETOMETER, USED FOR OBTAINING VARIATION OF THE MAGNETIC NEEDLE.

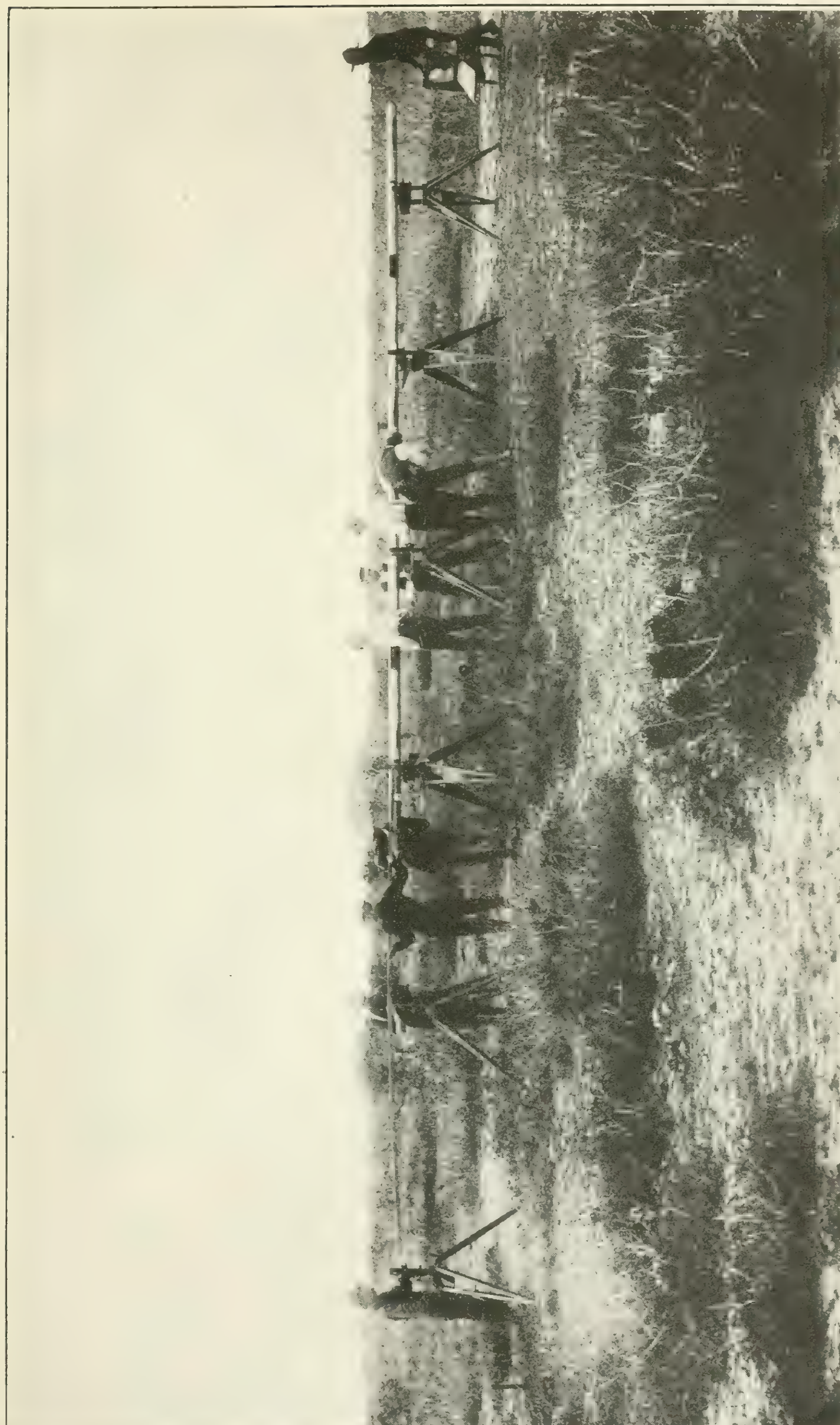


Fig. 7.—MEASURING A BASE LINE NEAR ALICE, TEX., WITH THE DUPLEX BARS, BEFORE THE INTRODUCTION OF INVAR TAPES.

Fig. 8.—MAKING THE REAR CONTACT IN MEASURING A BASE LINE WITH THE TAPE.

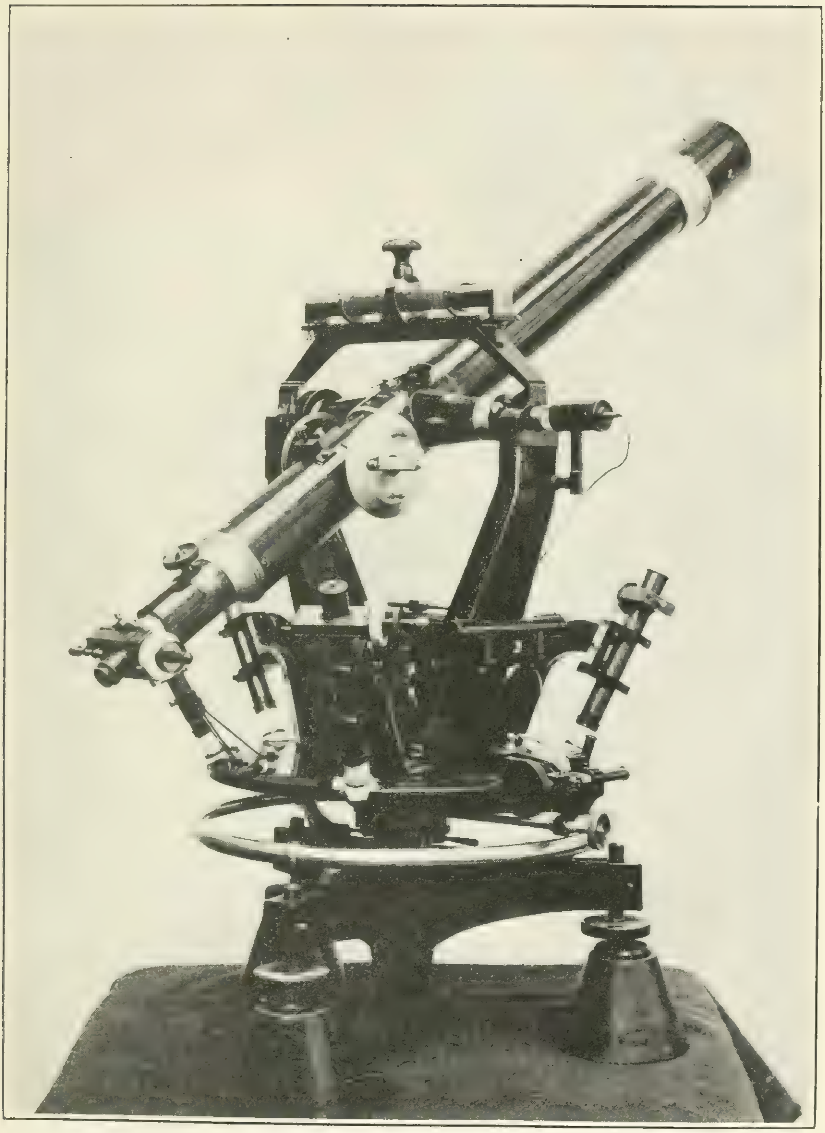


Fig. 10.—THEODOLITE, USED IN THE HIGHEST CLASS OF TRIANGULATION WHERE THE DISTANCES BETWEEN STATIONS ARE OFTEN 100 MILES OR MORE.

Fig. 11.—OBSERVER AT WORK ON THE COAST TRIANGULATION, MEASURING ANGLES FOR THE DETERMINATION OF THE POSITIONS OF OBJECTS USED TO CONTROL THE TOPOGRAPHIC AND HYDROGRAPHIC SURVEYS.

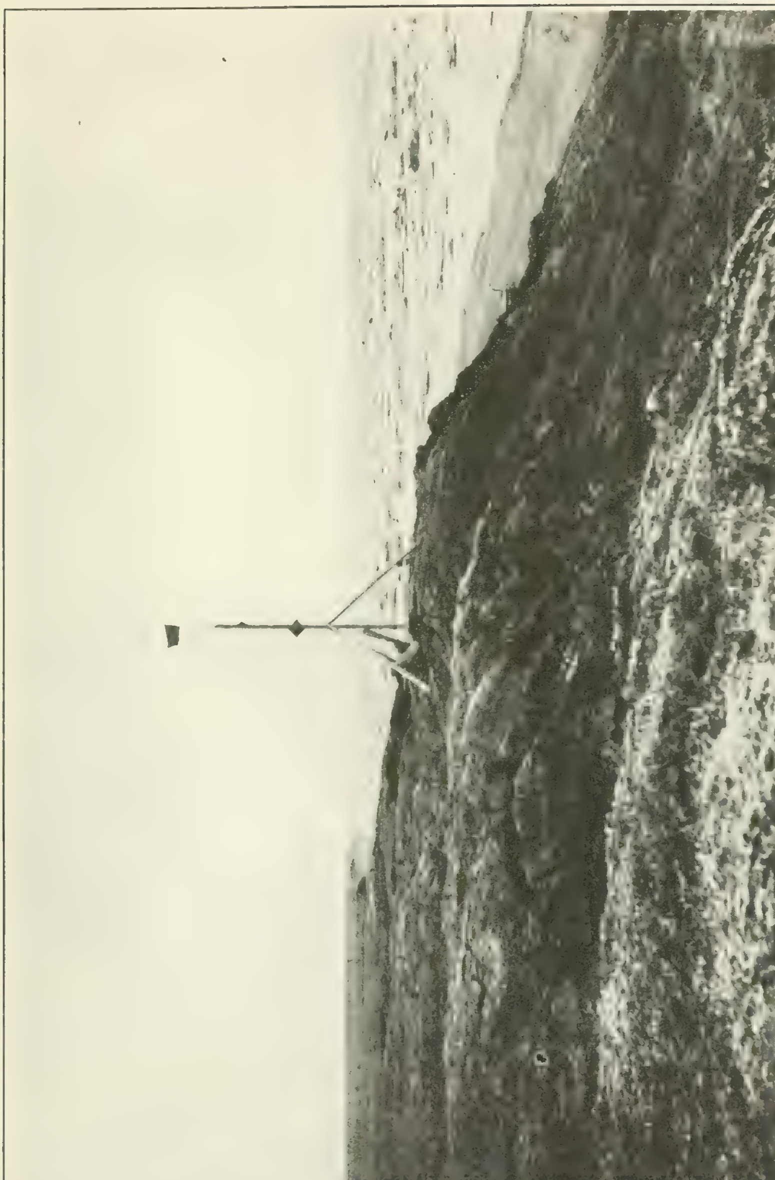


Fig. 12.—TRIANGULATION SIGNAL ON THE ARCTIC COAST OF ALASKA.

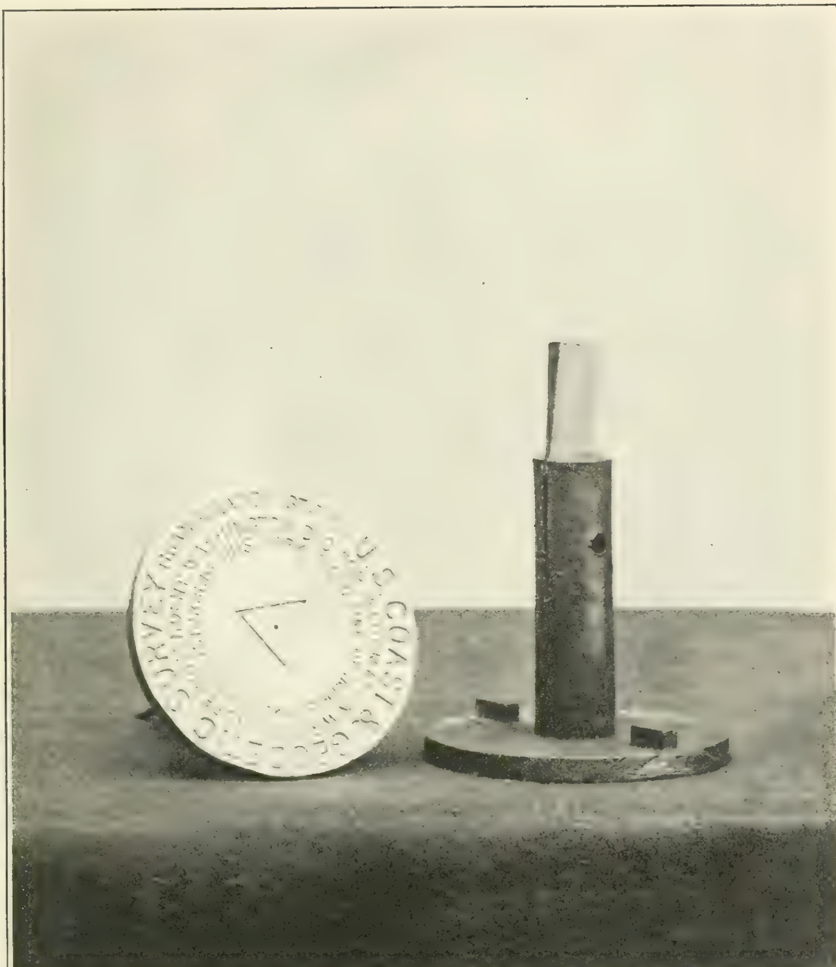


Fig. 13.—ALL TRIANGULATION STATIONS ARE PERMANENTLY MARKED WITH BLOCKS OF CONCRETE INTO WHICH IS SET A BRONZE TABLET OF THE TYPE SHOWN HERE.

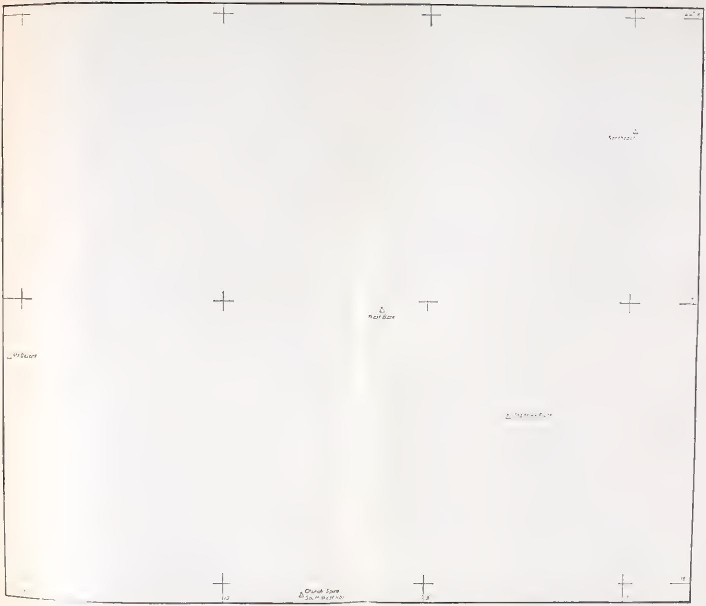
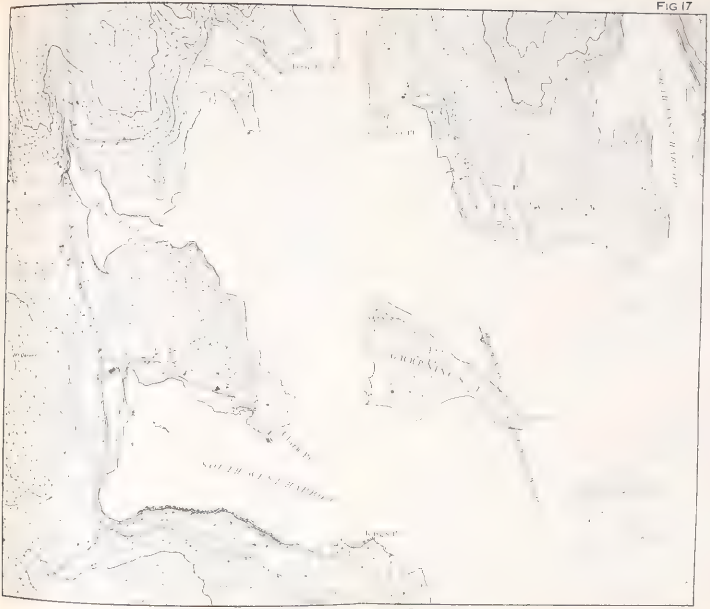


Fig. 14 [illegible]

Fig. 15.—MAPPING THE LAND AREAS WITH THE PLANE TABLE.

Fig. 16.—TOPOGRAPHY WITH THE PLANE TABLE UNDER DIFFICULTIES.
(PHILIPPINES.)

FIG 17



COMPLETED TOPOGRAPHIC SURVEY

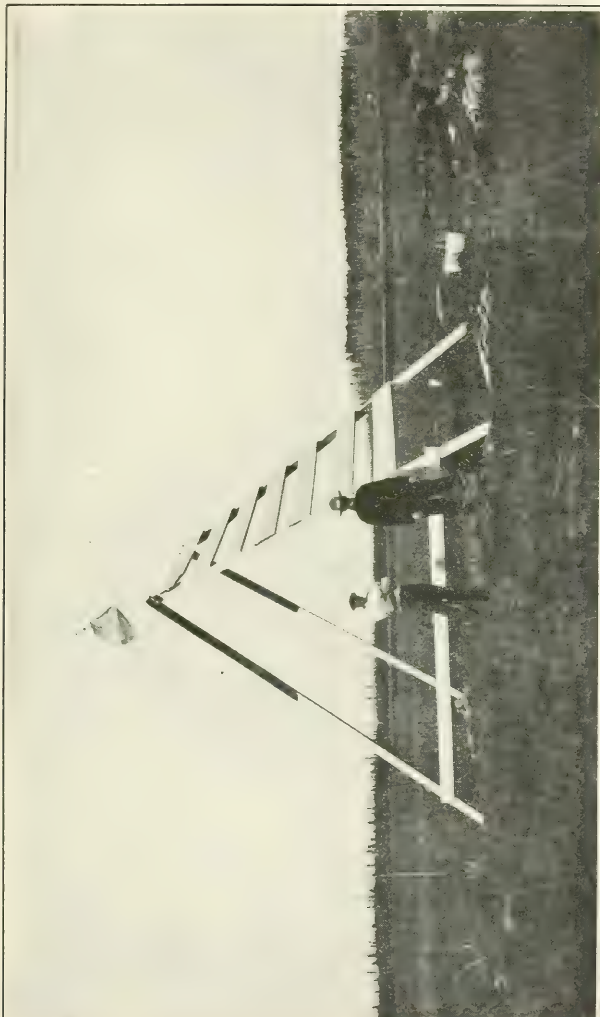


Fig. 18.—HYDROGRAPHIC SIGNAL IN ALASKA FOR WORK NEAR SHORE.

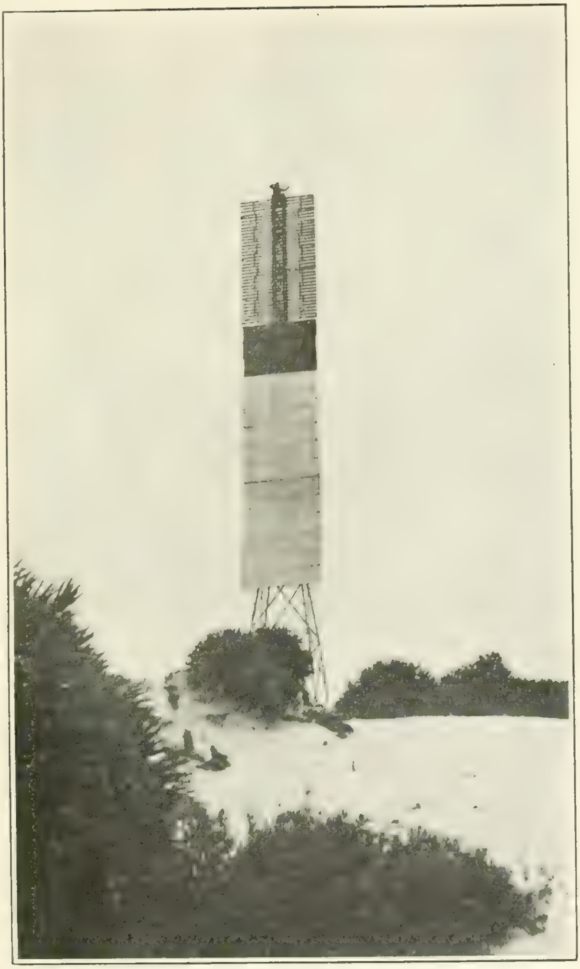
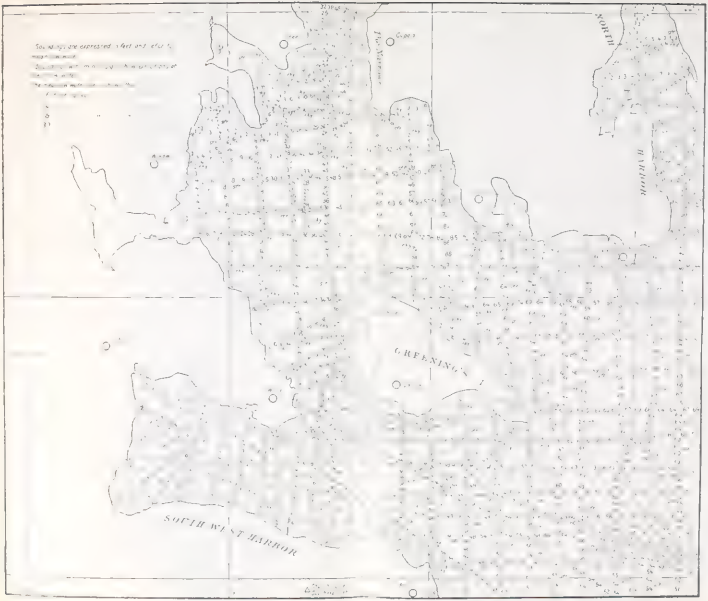


Fig. 19.—LARGE HYDROGRAPHIC SIGNAL, 75 FEET HIGH, USED IN OFFSHORE WORK ALONG THE COAST OF GEORGIA.

Fig. 20.—FLOATING HYDROGRAPHIC SIGNAL, USED FOR DETERMINING POSITIONS OF SOUNDINGS OUT OF SIGHT OF LAND.


The Narrows
NORTH
EAST HARBOR
GREENINGS
SOUTH WEST HARBOR



NORTH
HARBOR
GREENING
SOUTH WEST HARBOR

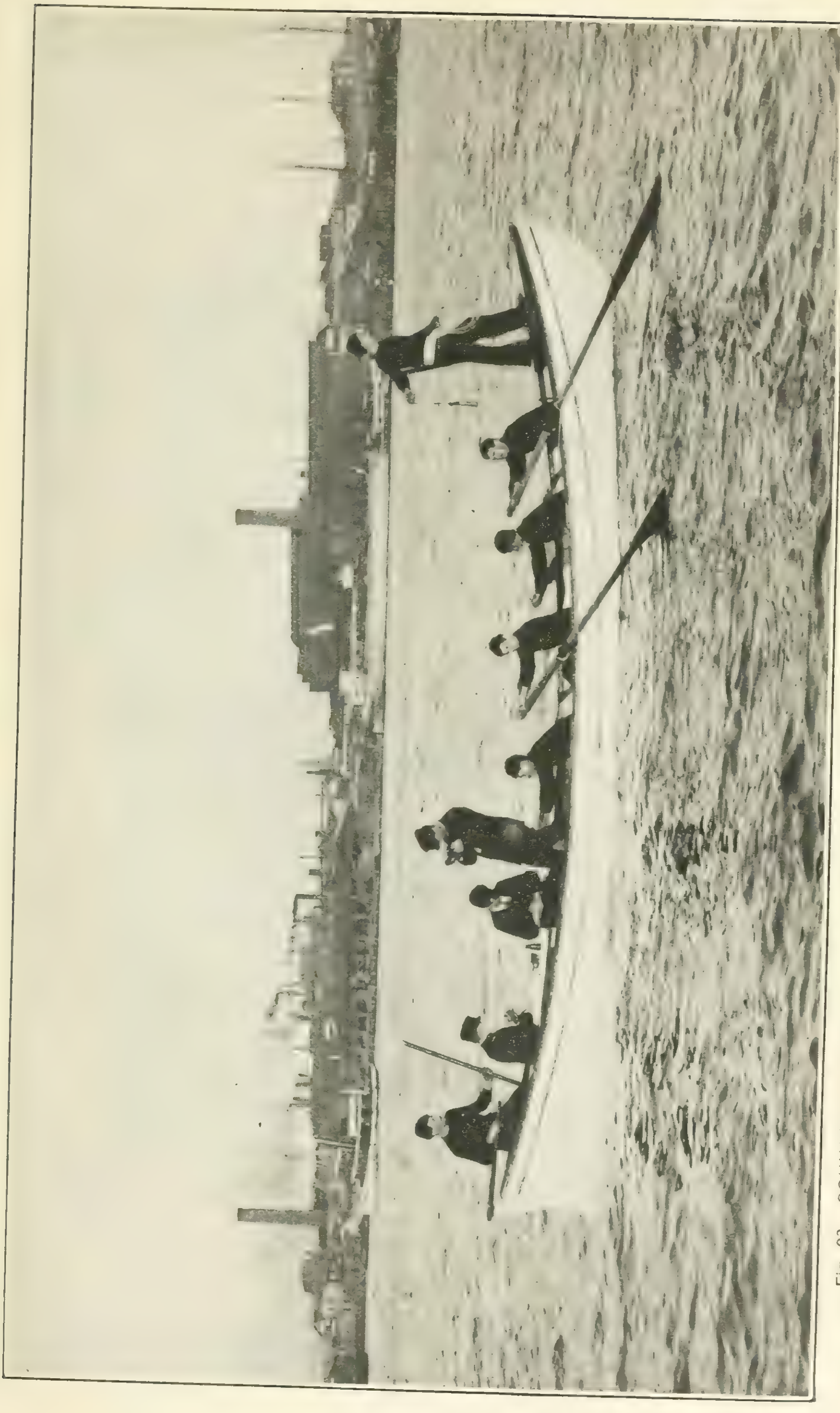


Fig. 23.—SOUNDING BY HAND FROM A WHALEBOAT IN COMPARATIVELY SHALLOW WATER, BALTIMORE HARBOR.

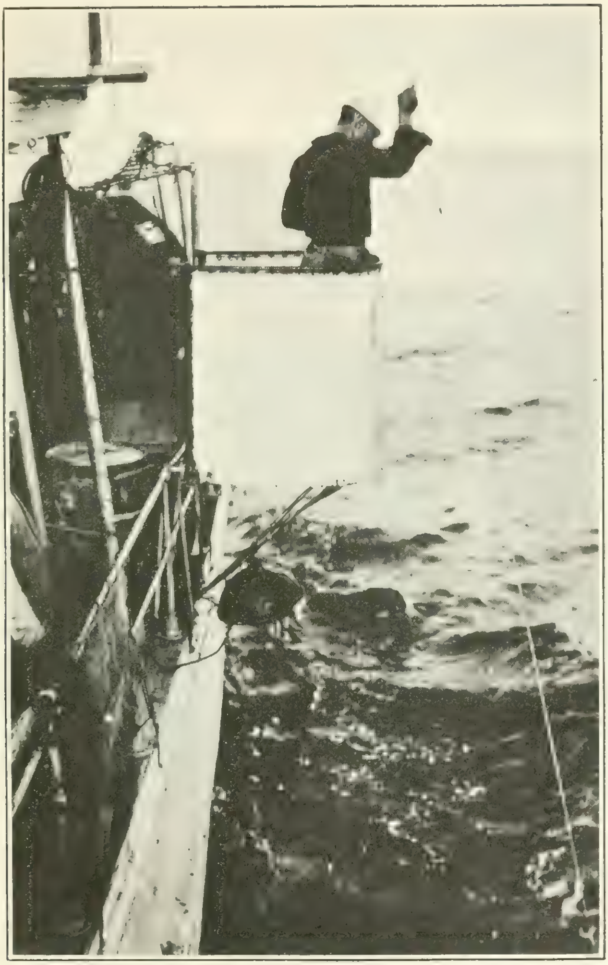


Fig. 24.—SOUNDING BY HAND FROM A SHIP IN COMPARATIVELY SHALLOW WATER.

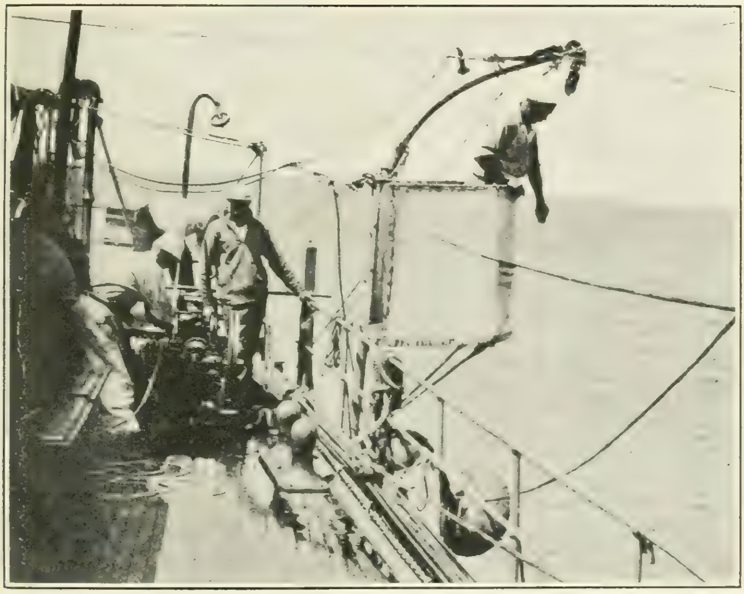


Fig. 25.—SOUNDING FROM A SHIP IN FAIRLY DEEP WATER, USING A HEAVY LEAD AND A HOISTING MACHINE.

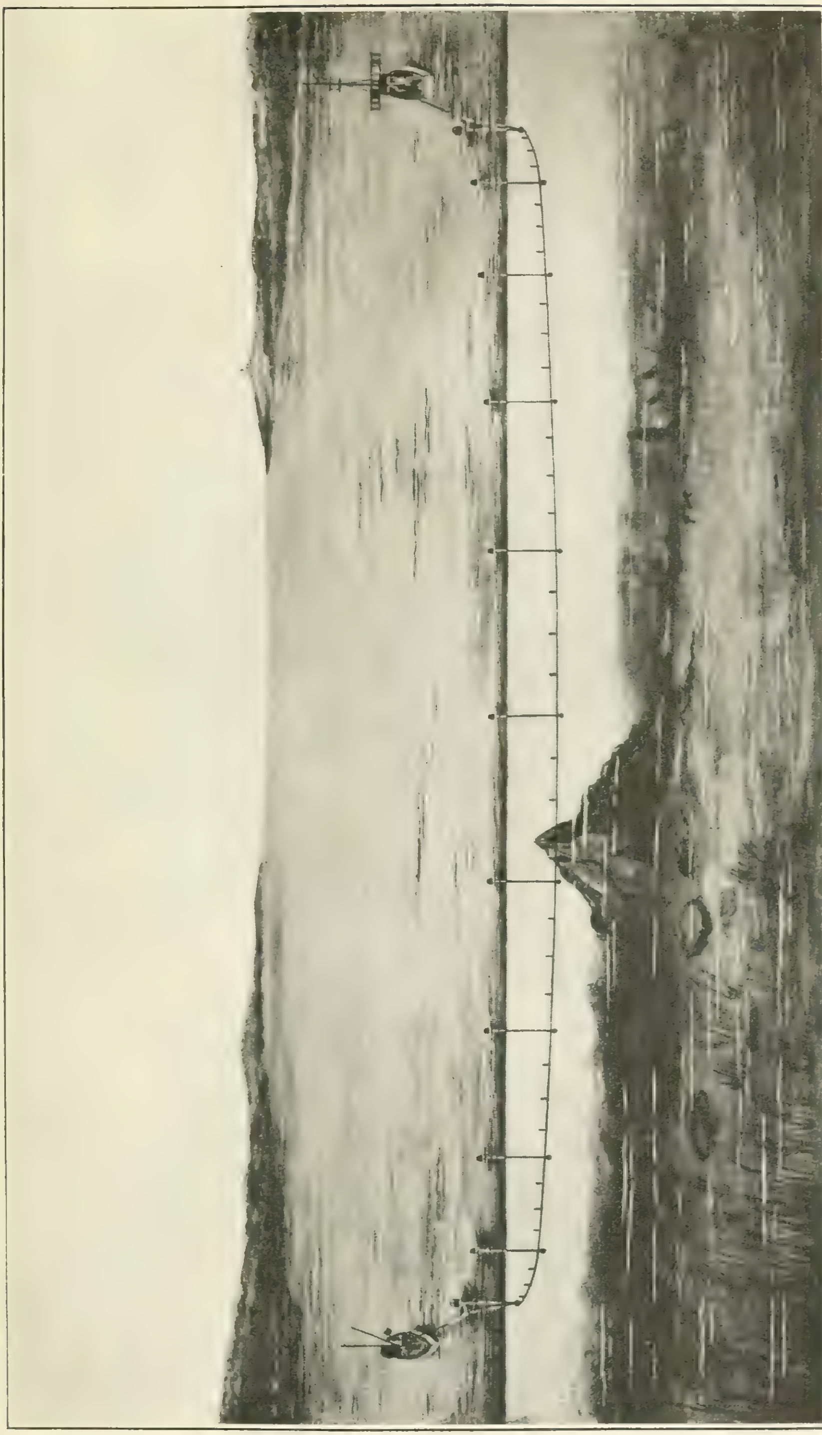
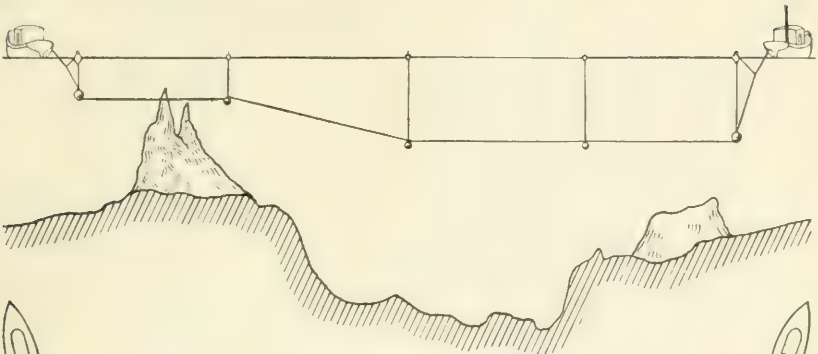
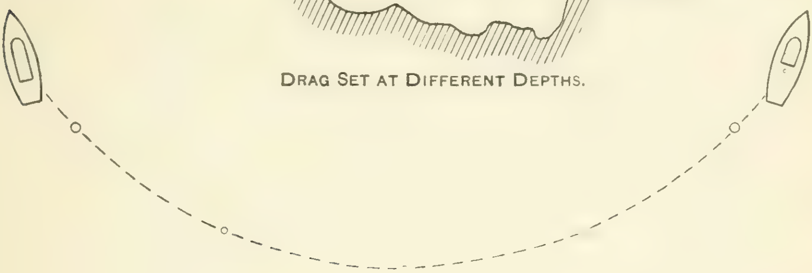


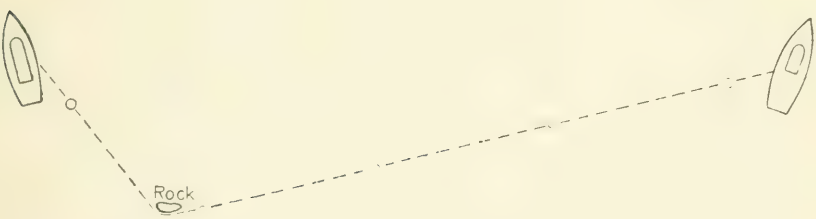
Fig. 26.—NEW AND IMPROVED FORM OF WIRE DRAG USED BY THE COAST AND GEODETIC SURVEY.



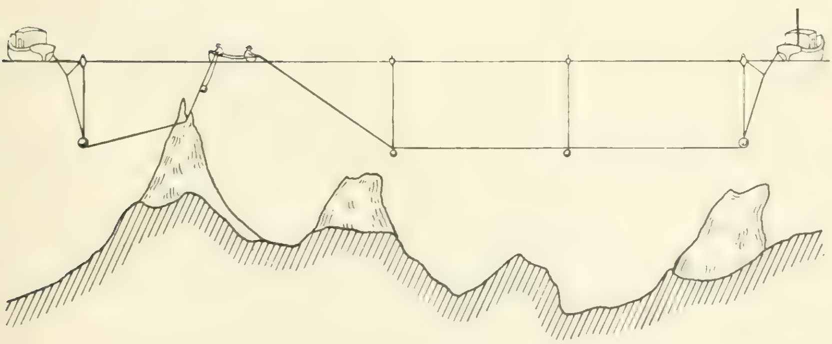
Drag Set at Different Depths.



Plan of Drag Under Way.



Plan of Drag Aground.



Clearing Drag.

Fig. 27.—DIAGRAM OF WIRE DRAG OPERATING.

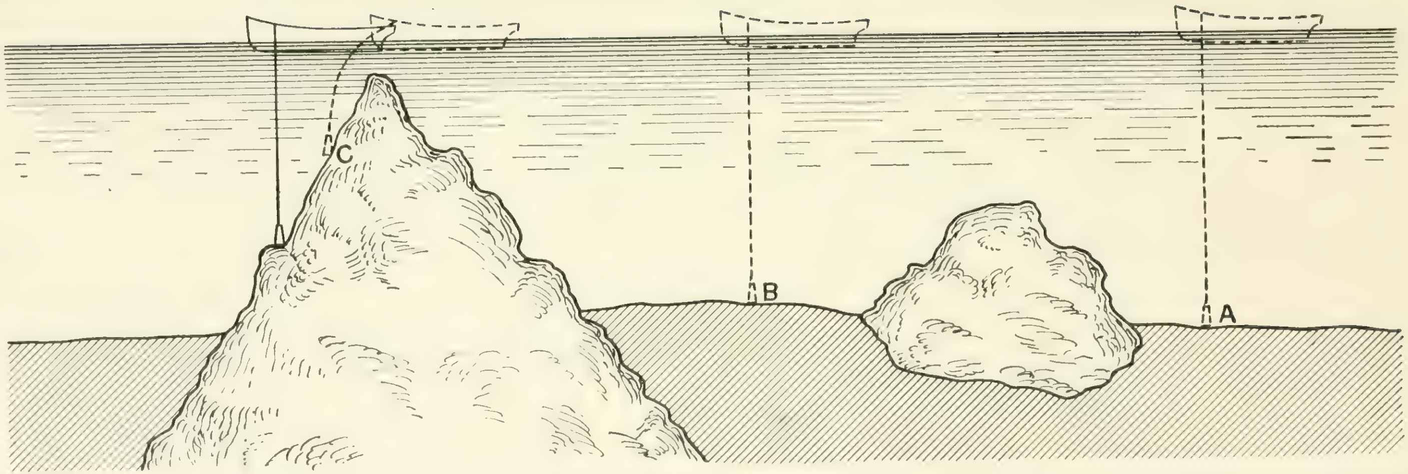


Fig. 28.—DIAGRAM SHOWING THE FAILURE OF THE SOUNDING LEAD AT CASTS "A" AND "B" TO INDICATE THE PRESENCE OF A BOWLDER AND, BY TOUCHING THE STEEP SIDE OF A PINNACLE ROCK AT "C," SLIPPING DOWN ITS SIDE AND GIVING A DEPTH OF MANY FATHOMS, ALTHOUGH A BOAT'S LENGTH AWAY THE ROCK RISES TO WITHIN A FEW FEET OF THE SURFACE.

The wire drag, now extensively used by the Coast and Geodetic Survey, makes certain the discovery of all rocks and shoals in the area dragged.

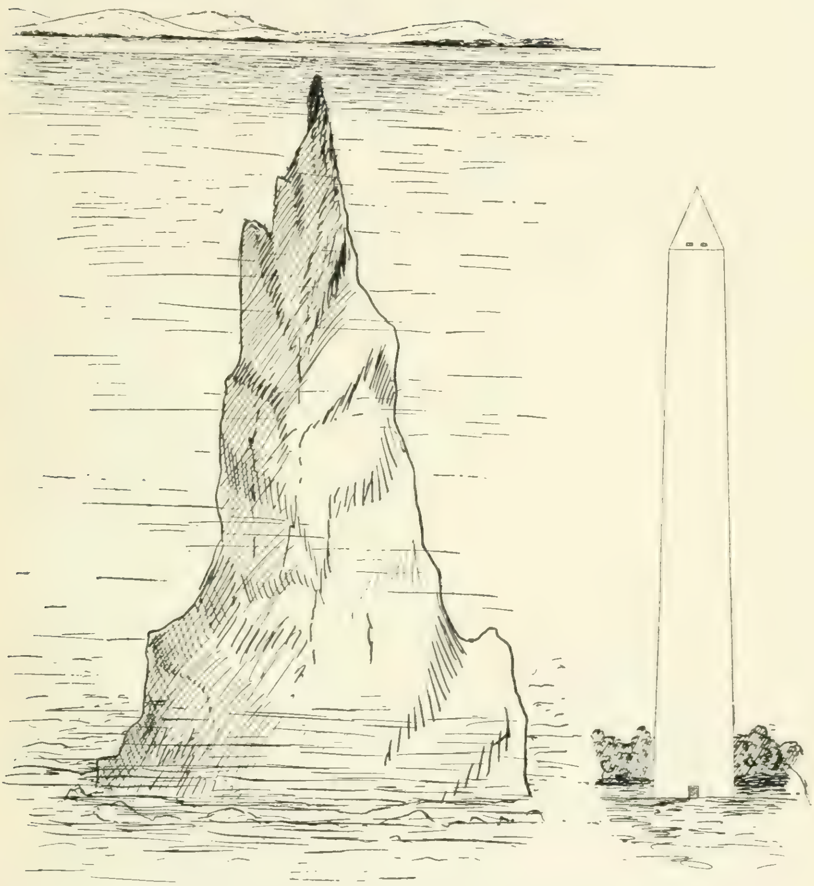


Fig. 29.—THE SUBMERGED "WASHINGTON MONUMENT" (PINNACLE ROCK), HEIGHT 650 FEET, FOUND IN ALASKAN WATERS IN 1915 BY THE WIRE DRAG. BUT 17 FEET OF WATER COVERS THIS PINNACLE. THE WASHINGTON MONUMENT WE KNOW SO WELL IS 555 FEET.

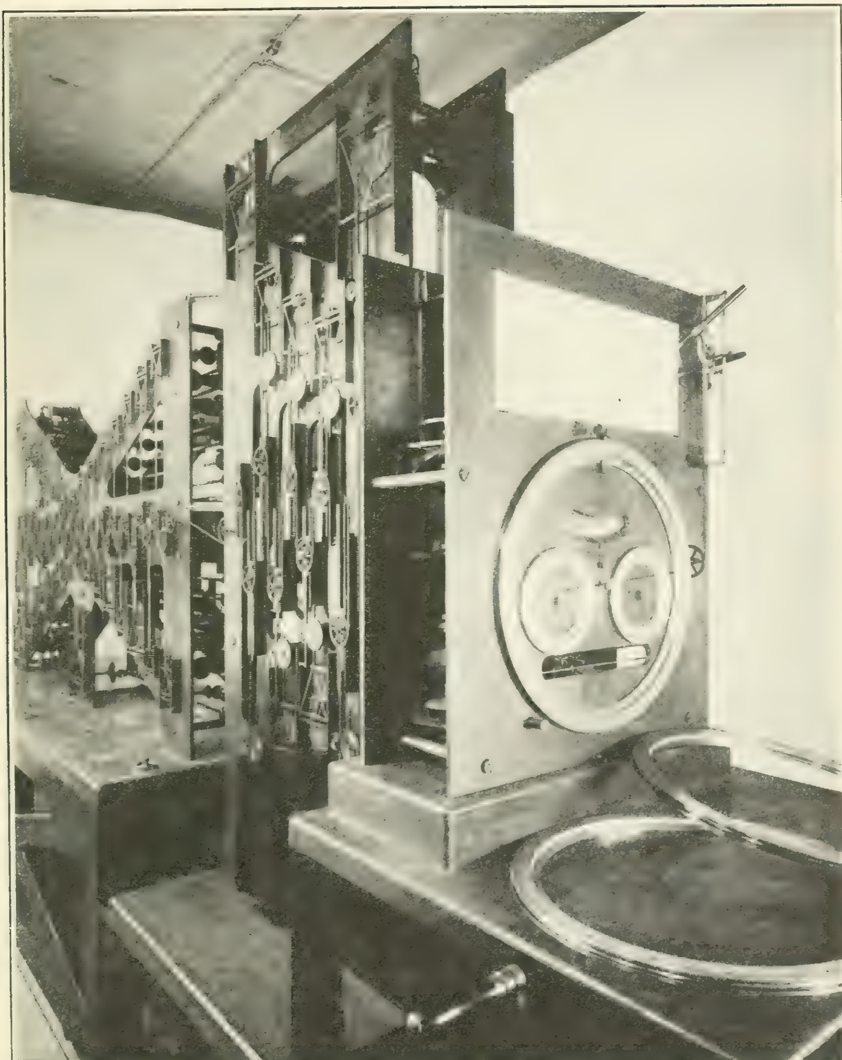
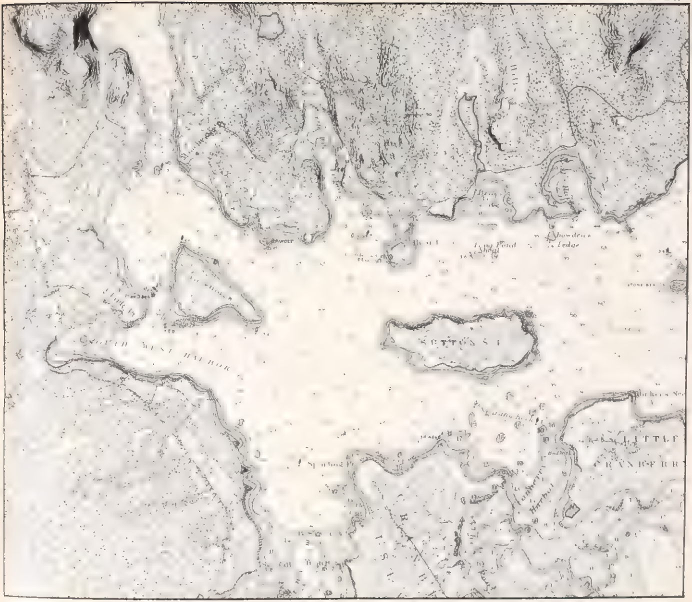


Fig. 30.—TIDE-PREDICTING MACHINE.

FIG. 31.



SPECIMEN OF NAUTICAL CHART—MOUNT DESERT ISLAND, MAINE

Note: sft indicates soft bottom; rky rocky bottom; buoys; water areas 18 feet or less in depth are dotted

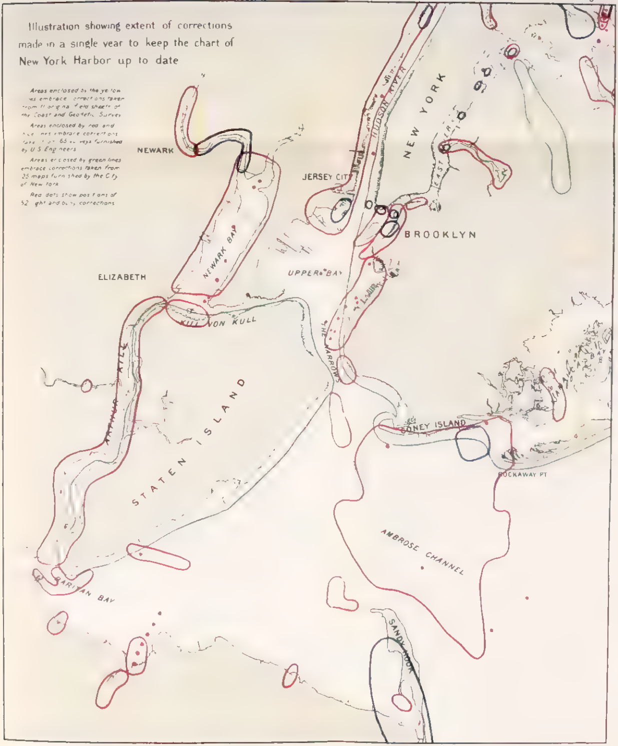


Illustration showing extent of corrections made in a single year to keep the chart of New York Harbor up to date
NEWARK
JERSEY CITY
HUDSON RIVER
NEW YORK
EAST RIVER
BROOKLYN
NEWARK BAY
ELIZABETH
UPPER BAY
KILL VON KULL
THE NARROWS
ARTHUR KILL
STATEN ISLAND
CONEY ISLAND
ROCKAWAY PT
AMBROSE CHANNEL
RARITAN BAY
SANDY HOOK